Port of Seattle

EAST WATERWAY OPERABLE UNIT
SUPPLEMENTAL REMEDIAL INVESTIGATION/ FEASIBILITY STUDY
FINAL DATA REPORT
BENTHIC INVERTEBRATE TISSUE AND CO-LOCATED SEDIMENT SAMPLES

For submittal to:

The US Environmental Protection Agency
Region 10
Seattle, WA

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Prepared by:

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Acronyms

Acronym	Definition
ACG	analytical concentration goal
ARI	Analytical Resources, Inc.
CCV	continuing calibration verification
CFR	Code of Federal Regulations
COC	chain of custody
CSL	cleanup screening level
CVAA	cold vapor atomic absorption
DCM	dichloromethane
DMMP	Dredged Material Management Program
dw	dry weight
EPA	US Environmental Protection Agency
EW	East Waterway
GC/ECD	gas chromatography/electron capture detection
GC/MS	gas chromatography/mass spectrometry

Acronym	Definition
GPS	global positioning system
HPAH	high-molecular-weight polycyclic aromatic hydrocarbon
ICP-AEA	inductively coupled plasma-atomic emission spectrometry
ICP-MS	inductively coupled plasma-mass spectrometry
ID	identification
LPAH	low-molecular-weight polycyclic aromatic hydrocarbon
MDL	method detection limit
ML	maximum limit
MLLW	mean lower low water
MS	matrix spike
MSD	matrix spike duplicate
NOAA	National Oceanic and Atmospheric Administration
OC	organic carbon
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PM	project manager
PSEP	Puget Sound Estuary Program
QAPP	quality assurance project plan
QA/QC	quality assurance/quality control
RL	reporting limit
SDG	sample delivery group
SIM	selected ion monitoring
SL	screening level
SPI	sediment profile imaging
SQS	sediment quality standards
SRM	standard reference material
TOC	total organic carbon
TBT	tributyltin
Windward	Windward Environmental LLC
ww	wet weight

1 Introduction

This data report presents the results of chemical analyses of benthic invertebrate tissue and co-located surface sediment samples collected as part of the supplemental remedial investigation for the East Waterway (EW). Sampling and analyses of these samples were conducted in accordance with the benthic invertebrate quality assurance project plan (QAPP) (Windward 2008).

Data collected in this study will be used in the ecological risk assessment for three purposes:

1. To assess the dietary exposure of receptors of concern that feed on the benthic community
2. To assess risks to benthic invertebrates from polychlorinated biphenyls (PCBs), mercury, and tributyltin (TBT) from a critical tissue-residue approach
3. To determine if it is possible to develop relationships between benthic tissue concentrations and co-located sediment concentrations

This report is organized into sections that address field and laboratory methods, chemical analytical results, and references. The text is supported by the following appendices:

- Appendix A – data management
- Appendix B – tributyltin memorandum
- Appendix C – data validation reports
- Appendix D - raw laboratory data
- Appendix E – collection forms and field notes
- Appendix F – chain-of-custody (COC) forms
- Appendix G – SPI data report

2 Field Collection and Sample Processing Methods

This section describes the collection of benthic invertebrate tissue and co-located sediment samples, sample processing methods, and the sediment profile imaging survey. The field procedures are described in greater detail in the QAPP (Windward 2008). Field deviations from the QAPP are also presented. Copies of completed COC forms used to track sample custody are presented in Appendix F. Copies of field forms, notebooks, and laboratory forms are presented in Appendix E.

2.1 Sample Collection

Benthic invertebrate tissue samples and co-located surface sediment samples were collected in 13 subtidal areas (Table 2-1, Map 2-1). Sampling methods were in accordance with the QAPP and standardized procedures developed by the Puget Sound Estuary Program (PSEP 1997; EPA 2002). After each sediment sample was retrieved from the double 0.1 m^2 van Veen grab sampler, it was evaluated for acceptability in accordance with the QAPP. Sediment samples were collected to a depth of 11-17 cm. The minimum required tissue mass (45 g ww) was obtained from 5 to 11 acceptable grabs collected within each subtidal area. Coordinates for each grab are presented in Table 2-1.

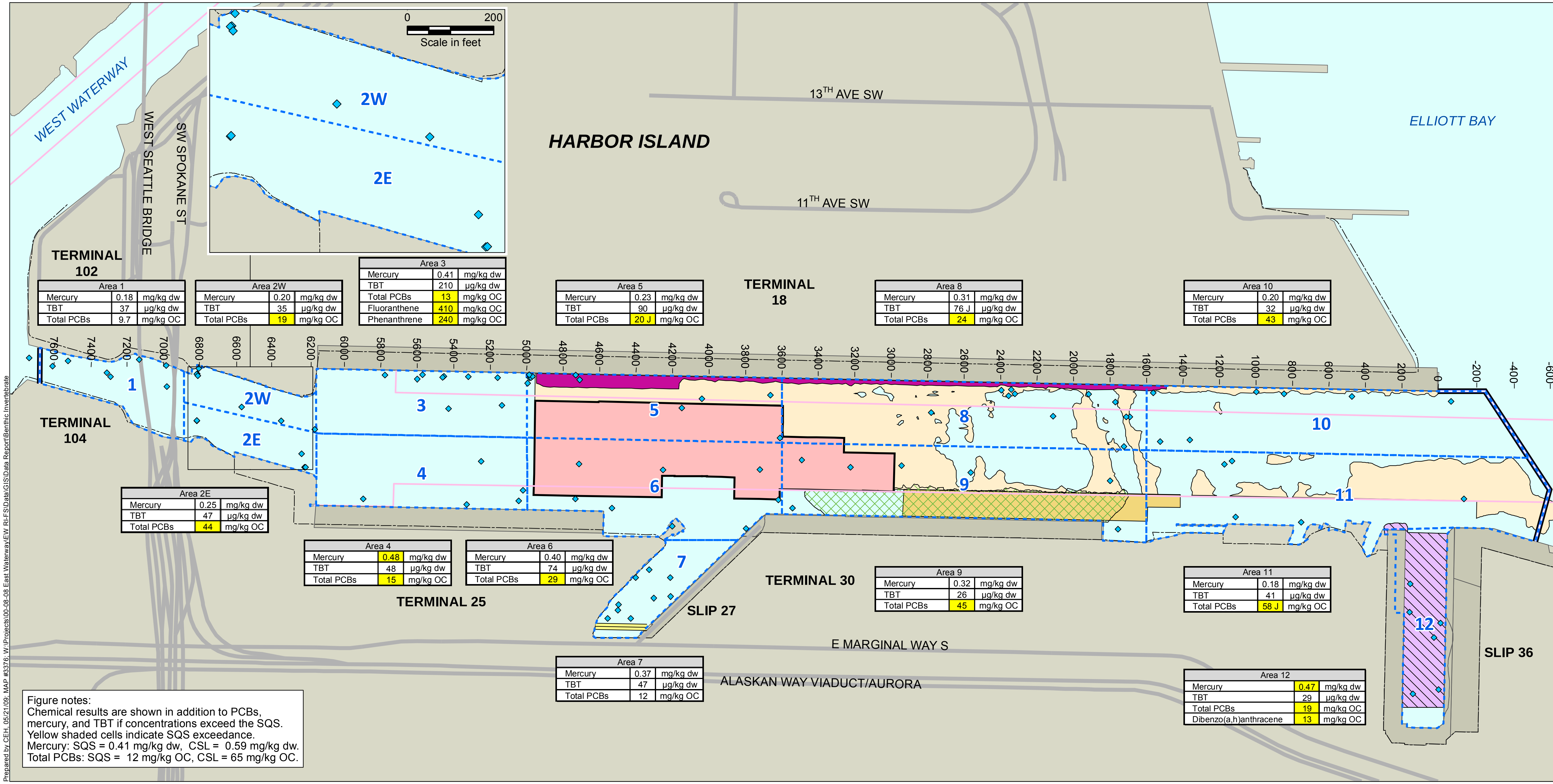
Table 2-1. Coordinates for benthic invertebrate sampling locations

Area	Sampling Location[a]		
	Grab No.	Latitude	Longitude
1	1	47.569885	-122.34609
	2	47.569303	-122.346135
	3	47.569657	-122.345965
	4	47.570476	-122.345844
	5	47.570529	-122.345757
	6	47.571364	-122.346031
	7	47.570955	-122.34615
	8	47.571381	-122.345571
2E	1	47.571838	-122.344823
	2	47.571842	-122.344831
	3	47.573473	-122.343836
	4	47.573484	-122.343837
	5	47.573423	-122.344136
2W	1	47.571832	-122.345861
	2	47.571852	-122.345978
	3	47.572509	-122.345146
	4	47.573615	-122.34468
	5	47.573104	-122.344855
	6	47.571824	-122.345855
	7	47.571841	-122.345814
3	1	47.576347	-122.345903
	2	47.576418	-122.345301
	3	47.575905	-122.345913
	4	47.575618	-122.345204
	5	47.575538	-122.345911
	6	47.575138	-122.34584
	7	47.574653	-122.345912
	8	47.57552	-122.345885
	9	47.575218	-122.345935

Area	Sampling Location[a]		
	Grab No.	Latitude	Longitude
4	1	47.576699	-122.343183
	2	47.57676	-122.343419
	3	47.576125	-122.344049
	4	47.575917	-122.343084
	5	47.574361	-122.343161
5	1	47.580604	-122.344698
	2	47.580448	-122.345639
	3	47.579423	-122.345531
	4	47.579124	-122.345319
	5	47.576825	-122.345916
	6	47.576797	-122.345798
	7	47.576847	-122.345918
	8	47.576871	-122.345947
	9	47.576821	-122.345979
	10	47.577581	-122.345898
	11	47.577516	-122.345994
6	1	47.579013	-122.342688
	2	47.578103	-122.343062
	3	47.577548	-122.343254
	4	47.577592	-122.344031
	5	47.580124	-122.342672
	6	47.580598	-122.343322
	7	47.580314	-122.343985
	8	47.578859	-122.343936
7	1	47.578068	-122.340618
	2	47.578222	-122.340805
	3	47.57823	-122.340928
	4	47.578478	-122.341531
	5	47.578678	-122.341711
	6	47.578418	-122.340626
	7	47.579008	-122.341126
	8	47.578997	-122.341543
	9	47.578756	-122.341083

Area	Sampling Location[a]		
	Grab No.	Latitude	Longitude
8	1	47.585782	-122.344655
	2	47.58586	-122.345315
	3	47.584034	-122.345729
	4	47.584706	-122.345295
	5	47.582874	-122.345328
	6	47.585239	-122.345804
	7	47.585642	-122.34564
	8	47.585808	-122.345312
	9	47.584128	-122.345779
	10	47.583923	-122.345854
	11	47.584074	-122.345874
9	1	47.585715	-122.342816
	2	47.585584	-122.343885
	3	47.580944	-122.344215
	4	47.580812	-122.343139
	5	47.581677	-122.344078
	6	47.582444	-122.344133
	7	47.583487	-122.344012
10	1	47.586323	-122.344781
	2	47.590681	-122.345799
	3	47.589192	-122.345869
	4	47.58817	-122.345894
	5	47.587754	-122.345929
	6	47.586204	-122.345864
	7	47.58677	-122.344828
11	1	47.588465	-122.34305
	2	47.58748	-122.343139
	3	47.58741	-122.344379
	4	47.590904	-122.34364
	5	47.587298	-122.344301
12	1	47.590581	-122.339402
	2	47.590193	-122.339292
	3	47.590496	-122.34055
	4	47.590589	-122.34088
	5	47.590121	-122.341107
	6	47.590122	-122.341732

[a] NAD 83 horizontal datum



Prepared by CEH, 05/21/09, MAP #3376, W:\Projects\00-08-08 East Waterway\EW RI-FS\Data\GIS\Data Report\Benthic Invertebrate

- Benthic tissue and co-located sediment location
- Tissue collection area boundary
- MHHW Line
- Dock/Pier
- Road
- Slip 27 Bridge
- Navigation channel
- East Waterway Study Area Boundary

Dredge Events (completion date)

- T-30 interim dredge (preliminary 2009, -51 MLLW)
- Stage 1a (completed 2006, -51 MLLW)
- Coast Guard dredge (completed 2005, -40 MLLW)
- Phase 1 removal action boundary (completed 2005, -51 MLLW)
- T-30 boundary (completed 2002, -51 MLLW)
- Stage 1 (completed 2000, -51 MLLW)

0 600
Scale in feet

Map 2-1
Sampling locations and results for PCBs, mercury, and TBT in sediment
Benthic Tissue Data Report
East Waterway Study Area

After acceptance of each sample, the following observations were noted in the field logbook: global positioning system (GPS) location, depth as read by the boat's depth sounder, gross characteristics of the surficial sediment (provided in Appendix E), and maximum penetration depth. Table 2-2 summarizes collection information for each subtidal area, including sampling dates and times.

Table 2-2. Collection information for benthic invertebrate samples

Area	Collection Date(s)	Time	Depth Below MLLW (ft)	Penetration Depth (cm)	Number of Double 0.12-m van Veen Grabs for Tissue Collection
1	10/27/2008	8:20-11:11	- 2.3 to - 24	11-14	8
2E	10/29/2008	8:13-10:15	- 2.5 to - 31.9	13-17	5
2W	10/29/2008	10:45-13:27	- 7.6 to - 41.8	11-16	7
3	10/28/2008	10:50-14:25	- 33.2 to - 43.7	14-17	9
4	10/28/2008	8:21-10:10	- 36.8 to - 51.7	14-17	5
5	10/27/2008; 10/28/2008	13:00-16:23; 14:55	- 37.7 to - 63	12-17	11
6	10/14/2008	14:00-16:30	- 32.5 to - 57.4	12-16	8
7	10/14/2008	9:20-13:31	- 12.2 to - 43.9	11-17	9
8	10/16/2008	11:57-16:00	- 51.4 to - 55.5	11-16	11
9	10/16/2008	8:22-11:00	- 16 to - 57.6	11-17	7
10	10/15/2008	11:19-16:22	- 53.8 to - 62.6	11-17	7
11	10/15/2008	9:09-10:45	- 29 to - 53.4	11-15	5
12	10/15/2008	12:55-14:40	- 37.6 to - 45.6	12-17	6

MLLW – mean lower low water

Each sediment grab was subsampled first for chemical analyses and then the remainder of the sample was sieved through a 1.0-mm mesh sieve to collect benthic invertebrates. For sediment chemistry samples, approximately 200 mL of sediment was removed from within each grab from a depth of 10 cm using a stainless steel spoon. At the laboratory, sediment from all grab samples at a given subtidal area was placed in one stainless steel bowl and stirred with a clean stainless steel spoon until texture and color became homogeneous. The homogenized sediment was then split into three pre-labeled jars and stored on ice in a cooler.

2.2 BENTHIC INVERTEBRATE TISSUE SAMPLE PROCESSING

Following the collection of sediment samples for chemical analyses, benthic invertebrates were collected from the remaining sediment within each grab. All benthic invertebrates except clams > 2 cm were included in the tissue composite samples, consistent with the specified market-basket approach for dietary analysis. The total biomass of the benthic invertebrate tissue and the clams > 2 cm (with shells) in each grab were measured separately, with an accuracy of 0.1 g ww. The benthic invertebrate tissue biomass (exclusive of clams greater than 2cm) from all of the grabs collected in an area was combined into one composite sample. Each of these composite samples was placed in a glass jar and stored on ice in a cooler. The clams > 2 cm were not submitted for chemical analyses but were instead individually archived frozen at Analytical Resources, Inc. (ARI). Table 2-3 summarizes the biomass for each grab and the total biomass for each subtidal area.

Table 2-3. Benthic Invertebrate and clam (> 2 cm) biomass from each grab sample and subtidal area

Area	Grab No.	Sample Weight (g ww)	
		Invertebrates	Clams (> 2 cm)
1	1	9.8	1.8
	2	6.0	0
	3	11.1	0
	4	19.6	0
	5	8.6	0
	6	7.6	0
	7	12.7	0
	8	6.9	0
	Total	**82.3**	**1.8**
2E	1	27.1	0
	2	2.9	0
	3	14.3	6.3
	4	8.1	0
	5	14.1	0
	Total	**66.5**	**6.3**
2W	1	12.1	0
	2	2.7	0
	3	7.1	0
	4	4.2	0
	5	7.8	0
	6	16.1	0
	7	12.2	0
	Total	**62.2**	**0**

Area	Grab No.	Sample Weight (g ww)	
		Invertebrates	Clams (> 2 cm)
3	1	3	0
	2	4.9	0
	3	4.3	0
	4	9.8	0
	5	10.2	0
	6	8.0	0
	7	6.7	0
	8	5.9	1.8
	9	4.7	0
	Total	**57.5**	**1.8**
4	1	13.4	0
	2	23.5	0
	3	2.8	0
	4	11.0	0
	5	7.8	5.3
	Total	**58.3**	**5.3**
5	1	1.6	0
	2	2.0	0
	3	2.1	0
	4	0.6	0
	5	5.7	0
	6	9.0	0
	7	5.5	0
	8	8.4	1.4
	9	10.6	0
	10	5.1	0
	11	9.7	0
	Total	**60.3**	**1.4**

Area	Grab No.	Sample Weight (g ww) Invertebrates	Clams (> 2 cm)
6	1	8.3	0
	2	10.5	0
	3	0.1	0
	4	16.1	0
	5	8.5	0
	6	8.3	0
	7	2.3	0
	8	12.4	0
	Total	**66.5**	**0**
7	1	6.3	0
	2	4.2	0
	3	7.0	0
	4	6.8	0
	5	9.3	0
	6	6.1	0
	7	4.1	0
	8	5.0	0
	9	8.0	0
	Total	**56.8**	**0**
8	1	7.5	0
	2	8.8	0
	3	10.8	0
	4	1.7	0
	5	1.0	0
	6	4.3	0
	7	2.4	0
	8	5.1	0
	9	4.9	0
	10	5.4	0
	11	8.8	0
	Total	**60.7**	**0**
9	1	8.3	0
	2	8.5	0
	3	8.6	0
	4	14.7	0
	5	5.1	0
	6	15.2	0
	7	9.0	0
	Total	**69.4**	**0**

Area	Grab No.	Sample Weight (g ww) Invertebrates	Clams (> 2 cm)
10	1	4.6	0
	2	8.2	0
	3	10.7	0
	4	6.0	1.0
	5	5.0	2.6
	6	9.8	0
	7	11.2	2.7
	Total	**55.5**	**6.3**
11	1	19.6	0
	2	15.4	0
	3	11.8	0
	4	3.0	0
	5	9.2	0
	Total	**59.0**	**0**
12	1	16.2	0
	2	8.0	0
	3	8.6	3.7
	4	9.3	0
	5	2.5	0
	6	6.7	0.9
	Total	**51.3**	**4.6**

ww – wet weight

2.3 SAMPLE IDENTIFICATION SCHEME

The first two characters of the location identification (ID) are "EW" to identify the East Waterway project area. The next two characters, "08," indicate that the sample was collected in 2008, and are followed by a four or five-character survey sampling area designation. The first four characters indicate the sampling area (BI01 through BI12); the fifth character indicates subarea (E[ast] or W[est]), where applicable. The final characters identify the sample matrix (sediment grab [S] and sequential number, benthic tissue [T], or composite sediment sample [Comp].

Examples of sample IDs are provided below:

- EW08-BI02W-T (East Waterway, 2008 benthic invertebrate tissue survey, sampling area 2W, benthic tissue)
- EW08-BI07-S3 (East Waterway, 2008 benthic invertebrate tissue survey, sampling area 7, third sediment grab)
- EW08-BI07-S-Comp (East Waterway, 2008 benthic invertebrate tissue survey, sampling area 7, sediment composite)

2.4 SPI SURVEY

In addition to the benthic tissue sampling described above, a visual assessment of benthic habitats and the benthic community successional stage was conducted in October 2008 using a sediment profile imaging (SPI) technique. This technique involves the use of a specialized platform-mounted camera that is extended into the surface sediment to take replicate photographs of the sediment surface (plan view) and sediment column (profile view). These images are then analyzed to characterize surface roughness, evidence of physical disturbance, apparent sediment grain size, stratification or layering within the sediment, depth of biological activity and oxygenated zone within the sediment, density of burrows or tubes, feeding voids and presence of wood waste or other debris. Methods and results of the SPI study are presented in detail in (Appendix G) and summarized below.

Replicate images of approximately the top 20 cm of sediment were collected from 63 stations (Figure 1 in Appendix G) between October 30 and 31, 2008. Metrics describing the benthic habitat and community successional stages were derived from an analysis of the images and included the dominant sediment grain size, average boundary roughness, average depth of the oxygenated layer (represented by the apparent redox potential discontinuity [aRPD] layer), and average depth of subsurface feeding voids. These data are summarized in Table 2-2, and summary statistics for the aRPD and feeding void depth are presented in Tables 2-3 and 2-4. The complete SPI data report is provided in Appendix G.

Table 2-4. SPI metrics describing the benthic habitat and community successional stages

Station	Grain Size Major Mode (phi)	Mean Boundary Roughness (cm)	Mean aRPD (cm)	Mean Feeding Void Depth (cm)
1-1A	> 4	1.33	1.76	nv
1-1B	> 4	3.90	2.25	nv
1-1C	> 4	2.69	indeterminate	nv
1-1D	indeterminate	indeterminate	indeterminate	nv
2-2A	2 to 1/> 4	0.80	1.67	nv
2-3A	3 to 2/> 4	1.63	1.02	nv
2-3B	3 to 2/> 4	1.49	1.37	nv
2-4A	> 4	1.62	0.95	nv
2-4B	3 to 2	0.96	3.59	nv
3-5A	> 4	1.07	2.61	nv
3-5B	> 4	1.10	3.29	3.72
3-5C	3 to 2/> 4	1.06	1.90	4.10
3-5D	> 4	0.83	1.90	6.34
3-6A	> 4	2.10	2.18	2.27
3-6B	> 4	0.90	2.11	4.32
3-6C	> 4	2.51	1.61	nv
3-6D	> 4	0.86	1.71	6.84
4-7A	> 4	0.57	2.18	2.51
4-7B	> 4	0.66	1.88	8.28
4-7C	> 4	0.60	1.85	nv
4-7D	> 4	0.85	2.24	nv
4-8A	> 4	0.34	2.32	nv
4-8B	> 4	0.97	2.65	nv
4-8C	2 to 1	0.55	5.07	nv
4-8D	3 to 2/> 4	0.89	2.57	nv
4-9A	> 4	1.60	1.32	5.58
4-9B	> 4	1.75	1.50	nv
4-9C	0 to -1/> 4	0.94	0.99	3.09
4-9D	4 to 3/> 4	0.79	2.14	2.74
4-10B	4 to 3/> 4	0.61	2.37	5.28
4-10C	> 4	1.66	1.36	2.11
4-10D	4 to 3/> 4	0.75	2.06	nv
4-11B	4 to 3/> 4	0.53	2.99	nv
4-11C	> 4	2.08	0.98	3.27
4-11D	> 4	1.79	0.56	3.86
4-12B	4 to 3/> 4	1.00	1.49	2.60
4-12C	3 to 2/> 4	1.47	1.91	nv
4-12D	4 to 3/> 4	0.73	2.46	nv
5-13A	4 to 3/> 4	0.81	1.92	5.94

Station	Grain Size Major Mode (phi)	Mean Boundary Roughness (cm)	Mean aRPD (cm)	Mean Feeding Void Depth (cm)
5-13B	3 to 2/> 4	0.68	2.55	8.98
5-13C	3 to 2/> 4	0.67	2.25	nv
5-13D	4 to 3	1.28	1.73	nv
5-14A	3 to 2/> 4	1.18	1.68	3.38
5-14B	3 to 2/> 4	0.61	1.82	nv
5-14C	4 to 3/> 4	0.86	0.83	nv
5-14D	4 to 3/> 4	2.10	2.12	3.38
5-15A	4 to 3/> 4	1.17	1.73	3.18
5-15B	4 to 3	0.59	2.12	nv
5-15C	3 to 2/> 4	0.64	2.04	nv
5-15D	4 to 3	1.08	2.08	nv
5-16B	3 to 2	0.80	2.32	nv
5-16C	3 to 2/> 4	0.84	2.36	nv
5-16D	4 to 3	0.61	2.18	nv
5-17A	3 to 2/> 4	0.86	1.83	nv
6-18A	>4	1.15	2.08	6.91
6-18B	>4	1.10	2.06	nv
6-18C	>4	0.82	2.31	7.91
6-18D	>4	0.44	2.97	nv
7-19A	4 to 3/> 4	1.22	2.41	1.48
7-19B	4 to 3/> 4	0.78	2.15	nv
7-19C	4 to 3/> 4	1.20	3.10	nv
7-19D	4 to 3/> 4	1.29	2.21	nv
7-19E	4 to 3/> 4	0.81	2.55	nv

aRPD – apparent redox potential discontinuity
nv – no value (no feeding voids)
SPI – sediment profile imaging

Table 2-5. aRPD layer in EW sediment

Summary Statistic	Replicate Mean (cm)	Station Mean (cm)
Minimum	0.2	0.6
Maximum	5.1	5.1
Average	2.1	2.1
Count	172	61
Standard deviation	0.77	0.70
95th UCL	2.2	2.2

EW – East Waterway
aRPD – apparent redox potential discontinuity
UCL – upper confidence limit

Table 2-6. Feeding void depth in EW sediment

Summary Statistic	Replicate Min (cm)	Replicate Max (cm)	Replicate Mean (cm)	Station Mean (cm)
Minimum	2.3	na	2.4	4.4
Maximum	na	18.3	17.8	17.8
Average	8.3	9.7	9.0	9.1
Standard deviation	3.23	3.33	3.10	2.95
95th UCL	9.3	10.8	10.0	10.3
Total number of images	189	189	189	63
Number of replicates deeper than 10 cm	10	17	12	9
Percent exceeding 10 cm	0.05	0.09	0.06	0.14

EW – East Waterway
na – not applicable
UCL – upper confidence limit

The analysis of the SPI images identified the benthic community present in the EW as largely a mature (Stage 3) community characterized by larger, deeper burrowing, longer-lived organisms. In almost all cases, Stage 1 organisms (early colonizers that are typically smaller, shorter-lived) were found at the same locations as Stage 3 organisms (Appendix G).

The SPI data were also used to estimate the surface sediment depth that represents the greatest potential for benthic invertebrate exposure for the ecological risk assessment. According to Washington State Department of Ecology (Ecology) guidance for characterizing surface sediments under the Washington State Sediment Management Standards (SMS) (Ecology 2008), the exposure potential and sediment unit of concern is the "biologically active zone" (often the top 10 cm). Past studies in Puget Sound have demonstrated that the majority of benthic macroinvertebrates are generally found within the uppermost 10 cm of sediments (Ecology 2008). Although some species may be found at greater depths below the sediment surface, 10 cm is generally assumed to represent a reasonable estimate of the biologically active zone. SPI data were used to provide site-specific information on the vertical distribution of benthic macroinvertebrates and the depth to anoxic sediments. Results from the 2008 SPI survey indicated that the top 10 cm is a reasonable estimate of the biologically active zone in EW and therefore the vertical extent of benthic invertebrate exposure in the sediment of EW. The aRPD depth (a representation of the well-mixed, oxygenated sediment layer) ranged from < 1.0 to 5.1 cm, with an average of 2.0 cm. Individual worm tubes or feeding voids extended beyond the aRPD in a number of cases, to an average depth of 9.0 cm. The maximum depth of any biological activity was recording as 18 cm; however, feeding voids > 10 cm only occurred in less than 15% of the cases.

2.5 FIELD DEVIATIONS FROM THE QAPP

Field deviations from the QAPP were as follows:

- The QAPP discussed the collection of gastropods for an evaluation of the prevalence of imposex/intersex. This survey has not been conducted. Notes on the abundance of gastropods are provided in Appendix E. If the gastropod survey is conducted in the future the results will be provided in a separate data memo.
- The QAPP specified 10 grabs per subtidal area. Fewer than 10 grabs were collected in all areas, except Areas 5 and 8, because sufficient tissue mass was obtained with 5 to 9 grabs.
- Benthic tissue samples collected October 27 to 29, 2008, were identified with "BI" instead of "T" as outlined in the QAPP.
- One of the benthic tissue samples included in the composite sample for Area 1 (EW08-BI01-S2) was collected just outside of the study area boundary (Map 2-1). This field deviation is not expected to substantially affect the representativeness of this sample for Area 1 because it was collected close to the study area boundary and the sample mass was a relatively small percentage of the total composite mass (i.e., 6 g of the total 82.3 g, or 7%).
- An additional sampling event was conducted to provide additional TBT data for benthic tissue and sediment. Descriptions of this sampling event and the results of the sampling event are provided in Appendix B.

3 Laboratory Methods

The methods and procedures used to chemically analyze the tissue and sediment samples are described briefly in this section and in detail in the benthic invertebrate QAPP (Windward 2009). This section also summarizes any laboratory deviations from the QAPP.

Benthic invertebrate tissue and sediment samples were hand-delivered to ARI, where they were homogenized into composite samples according to the compositing scheme that was approved by EPA (e-mail from R. Sanga, 10/28/2008). Tissue samples were analyzed for PCB Aroclors, total metals (including mercury), butyltins, lipids, and polycyclic aromatic hydrocarbons (PAHs). All co-located sediment samples were analyzed for total organic carbon (TOC), grain size, total solids, PCB Aroclors, total metals (including mercury), butyltins, and PAHs.

3.1 Tissue Analytical Methods

Tissue analytical testing adhered to the most recent EPA quality assurance and quality control (QA/QC) guidelines and analysis protocols (PSEP 1997; EPA 2002). Chemical analysis methods are identified in Table 3-1. All methods selected represent standard methods used for the analysis of these analytes in tissue.

Table 3-1. Analytical methods for benthic invertebrate tissue analyses

Parameter	Method	Reference	Sample Holding Time[a]	Preservative
PCBs as Aroclors	GC/ECD	EPA 8082	1 year to extract, 40 days to analyze	freeze/-20°C
PAHs[b]	GC/MS-SIM	EPA 8270D-SIM	1 year to extract, 40 days to analyze	freeze/-20°C
Tributyltin, dibutyltin, monobutyltin (as ions)	GC/MS-SIM	Krone et al. (1989)	1 year to extract, 40 days to analyze	freeze/-20°C
Total mercury	CVAA	EPA 7471A	6 months	freeze/-20°C
Total metals[c]	ICP-MS and ICP-AES	EPA 6020 and EPA 6010B	6 months	freeze/-20°C
Lipids	DCM: acetone gravimetric extraction	NOAA (1993)	1 year	freeze/-20°C

[a] All samples will be archived frozen at the laboratory until the Windward PM or QA/QC officer authorizes their disposal.

[b] Target PAHs include: anthracene, pyrene, dibenzofuran, benzo(g,h,i)perylene, indeno(1,2,3-cd)pyrene, benzo(b)fluoranthene, fluoranthene, benzo(k)fluoranthene, acenaphthylene, chrysene, benzo(a)pyrene, dibenz(a,h)anthracene, benzo(a)anthracene, acenaphthene, phenanthrene, fluorene, 1-methylnaphthalene, naphthalene, and 2-methylnaphthalene.

[c] Antimony, arsenic, cadmium, chromium, cobalt, copper, lead, molybdenum, nickel, selenium, silver, thallium, vanadium, and zinc.

CVAA – cold vapor atomic absorption
DCM – dichloromethane
EPA – US Environmental Protection Agency
GC/ECD – gas chromatography/electron capture detection
GC/MS – gas chromatography/mass spectrometry
ICP-AES – inductively coupled plasma-atomic emission spectrometry
ICP-MS – inductively coupled plasma-mass spectrometry
NOAA – National Oceanic and Atmospheric Administration
PAH – polycyclic aromatic hydrocarbon
PCB –polychlorinated biphenyl
PM – project manager
QA/QC – quality assurance/quality control
SIM – selected ion monitoring

3.2 SEDIMENT ANALYTICAL METHODS

Sediment analytical testing adhered to the most recent EPA QA/QC guidelines and analysis protocols (PSEP 1997; EPA 2002). Chemical analysis methods are identified in Table 3-2. All methods selected represent standard methods used for the analysis of these analytes in sediment.

Table 3-2. Analytical methods for sediment analyses

Parameter	Method	Reference	Sample Holding Time[a]	Preservative
PCBs as Aroclors	GC/ECD	EPA 8082	14 days to extract, 40 days to analyze[b]	cool/4°C
PAHs[c]	GC/MS-SIM	EPA 8270D	14 days to extract, 40 days to analyze[b]	cool/4°C
Tributyltin, dibutyltin, monobutyltin (as ions)	GC/MS-SIM	Krone et al. (1989)	14 days to extract, 40 days to analyze[b]	cool/4°C
Total mercury	CVAA	EPA 7471A	28 days[e]	cool/4°C
Total metals[d]	ICP-MS and ICP-AES	EPA 200.8 and EPA 6010B	1 year	cool/4°C
Grain size	sieve/pipette	PSEP (1986)	none	none
TOC	combustion	Plumb (1981)	28 days[e]	cool/4°C
Total solids	oven-dried	PSEP (1986)	7 days[e]	cool/4°C

[a] All samples will be archived frozen at the laboratory until the Windward PM or QA/QC officer authorizes their disposal.

[b] Sediment can also be frozen to increase the holding time to 1 year for extraction. Aqueous rinsate blanks have a maximum holding time of 7 days to extract and 40 days to analyze and will be stored at 4°C.

[c] Target PAHs include anthracene, pyrene, dibenzofuran, benzo(g,h,i)perylene, indeno(1,2,3-cd)pyrene, benzo(b)fluoranthene, fluoranthene, benzo(k)fluoranthene, acenaphthylene, chrysene, benzo(a)pyrene, dibenz(a,h)anthracene, benzo(a)anthracene, acenaphthene, phenanthrene, fluorene, 1-methylnaphthalene, naphthalene, and 2-methylnaphthalene.

[d] Antimony, arsenic, cadmium, chromium, cobalt, copper, lead, molybdenum, nickel, silver, selenium, thallium, vanadium, and zinc.

[e] Sediment may be frozen, with a maximum holding time of 6 months.

CVAA – cold vapor atomic absorption
EPA – US Environmental Protection Agency
GC/ECD – gas chromatography/electron capture detection
GC/MS – gas chromatography/mass spectrometry
ICP-AES – inductively coupled plasma-atomic emission spectrometry
ICP-MS – inductively coupled plasma-mass spectrometry
PAH – polycyclic aromatic hydrocarbon
PCB – polychlorinated biphenyl
PM – project manager
PSEP – Puget Sound Estuary Program
QA/QC – quality assurance/quality control
SIM – selected ion monitoring
TOC – total organic carbon

3.3 LABORATORY DEVIATIONS FROM THE QAPP

The laboratories followed the methods and procedures described in the QAPP with the following exceptions:

- ARI conducted additional processing of the benthic invertebrate tissue samples, removing shells from larger clams (1-2cm shell diameter) and also extracted a larger mass for PCB analysis than specified in the QAPP. This resulted in reduced sample mass; as a result, nine samples were not analyzed for TBT. The details of this deviation are presented in Appendix B. The quality of the data is not affected by this deviation.

- Butyltins were analyzed using gas chromatography/mass spectrometry (GC/MS) with selected ion monitoring. The QAPP (Windward 2009) listed butyltin analysis using gas chromatography/flame photometric detection in error. The quality of the data is not affected by this deviation.

4 Results of Chemical Analyses

This section presents the results of the chemical analyses and data validation of the benthic tissue and co-located sediment samples. Raw laboratory data are presented in Appendix D. The approach used to average laboratory replicates, and the methods for calculating total concentrations of PCBs and PAHs are presented in Appendix A. The number of significant figures shown for each concentration was as reported by the analytical laboratories.

QA review of the sediment and tissue chemistry data was conducted in accordance with the QA/QC requirements and technical specifications of the methods, and the national functional guidance for organic and inorganic data review (EPA 1999, 2004).

EcoChem, Inc. (EcoChem), conducted the data review and summary validation. The results of the data validation are discussed in Section 4.2, and presented in full in Appendix C. Explanations of data qualifiers for specific analytes and sample groups are provided in Section 4.2. A detailed discussion of each qualified sample is provided in Appendix C.

4.1 Analytical Results

This section presents the analytical chemistry results for both benthic invertebrate tissue and co-located sediment. The results are discussed separately below under each analyte group.

4.1.1 Metals

The results from the metals analyses of benthic invertebrate tissue and co-located sediment samples are presented in Sections 4.1.1.1 and 4.1.1.2, respectively.

4.1.1.1 Benthic invertebrate tissue

Table 4-1 presents a summary of the metals analyzed in benthic invertebrate tissue composite samples, including the number of detections, the range of detected metals concentrations, and the range of reporting limit (RLs). Results for all metals in benthic invertebrate tissue samples are presented in Table 4-2. Eight of the metals (antimony, arsenic, chromium, copper, mercury, selenium, vanadium, and zinc) were detected in all samples. Six other metals (cadmium, cobalt, lead, molybdenum, nickel, and thallium) were each detected in 5 to 8 samples. Silver was detected in only one sample. The highest concentrations of metals were detected in the following areas: Area 2E (thallium), Area 2W (arsenic and copper), Area 3 (selenium), Area 4 (molybdenum), Area 5 (nickel), Area 11 (cadmium), and Area 12 (cadmium, antimony, chromium, cobalt, lead, mercury, silver, vanadium, and zinc) (Table 4-2).

Table 4-1. Summary of metals data for benthic invertebrate composite tissue samples

Analyte	Detection Frequency	Detected Concentration (mg/kg ww)		Reporting Limit (mg/kg ww)
		Minimum	Maximum	Min – Max
Antimony	13/13	0.04 J	0.45 J	na
Arsenic	13/13	2.61	7.67	na
Cadmium	6/13	0.2	0.5	0.4 – 0.8
Chromium	13/13	2	10.6	na
Cobalt	5/13	0.5	0.6	0.6 – 1
Copper	13/13	15.8	36.4	na
Lead	6/13	3	20.4	4 – 8
Mercury	13/13	0.024	0.06	na
Molybdenum	8/13	0.7	3	0.5 – 2
Nickel	6/13	1 J	3 J	2 – 4
Selenium	13/13	0.5	1.2	na
Silver	1/13	0.1 J	0.1 J	0.3 – 1
Thallium	8/13	0.005	0.012	0.008 – 0.02
Vanadium	13/13	2.8	7.2	na
Zinc	13/13	17	79.7	na

J – estimated concentration
na – not applicable
ww – wet weight

Table 4-2. Concentrations of metals in individual benthic invertebrate composite tissue samples

Analyte	Concentration (mg/kg ww)												
	Area 1	Area 2E	Area 2W	Area 3	Area 4	Area 5	Area 6	Area 7	Area 8	Area 9	area 10	Area 11	Area 12
Antimony	0.059 J	0.196 J	0.199 J	0.048 J	0.08 J	0.187 J	0.07 J	0.06 J	0.05 J	0.04 J	0.05 J	0.10 J	0.45 J
Arsenic	5.04	4.90	7.67	4.04	3.16	3.6	3.46	4.2	2.7	2.61	3.2	4.28	4.66
Cadmium	0.2	0.2	0.4 U	0.2	0.8 U	0.3	0.4 U	0.4 U	0.4 U	0.8 U	0.4 U	0.5	0.20
Chromium	2.6	2.6	7	2.7	4	2.4	5	2	3	3	2	2	10.6
Cobalt	0.5	0.5	0.6 U	0.5	1 U	0.5	0.6 U	0.6 U	0.6 U	1 U	0.6 U	0.6 U	0.6
Copper	21.4	18.7	36.4	23.7	15.8	33.0	20.2	23.0	17.9	21.5	20.0	18.7	27.8
Lead	3	4	4 U	4	8 U	4	4 U	4	4 U	8 U	4 U	4 U	20.4
Mercury	0.024	0.030	0.050	0.05	0.04	0.05	0.038	0.03	0.04	0.036	0.05	0.040	0.06
Molybdenum	1	0.5 U	1 U	0.5 U	3	0.8	1	1	1 U	2 U	1	1	0.7
Nickel	1 J	1 J	2 U	1 J	4 U	2	3 J	2 U	2 U	4 U	2 U	2 U	1.7
Selenium	0.69	0.75	0.7	1.2	0.7	0.7	0.7	0.6	0.6	0.5	0.6	0.6 J	0.5 J
Silver	0.3 UJ	0.3 UJ	0.6 UJ	0.3 UJ	1 UJ	0.3 UJ	0.6 UJ	0.6 UJ	0.6 UJ	1 UJ	0.6 UJ	0.6 UJ	0.1 J
Thallium	0.005	0.012	0.007	0.009	0.009	0.008 U	0.008	0.011	0.02 U	0.02 U	0.02 U	0.02 U	0.010
Vanadium	2.8	4.0	3.2	4.2	3	3.8	4.5	4.5	2.9	5	3.6	2.9	7.2
Zinc	37	36	25	30	17	34	39	32	32	26	42	30	79.7

J – estimated concentration
U – not detected at reporting limit shown
ww – wet weight

4.1.1.2 Sediment co-located with benthic invertebrate tissue samples

Table 4-3 summarizes the metals analyzed in the co-located sediment composite samples, including the number of detections, the range of detected concentrations, and the range of RLs. All metals were detected in two or more sediment samples, except for antimony and selenium, which were not detected at any of the locations; and 11 of the 15 metals were detected in every sediment sample. The highest concentrations of metals were detected in the following areas: Area 3 (cobalt, copper, nickel, and vanadium), Area 4 (mercury), Area 5 (thallium), Area 7 (cadmium, molybdenum, and zinc), Area 10 (chromium), and Area 12 (arsenic, lead, and silver).

Table 4-3. Summary of metals data in composite sediment samples co-located with benthic invertebrate tissue samples

Analyte	Detection Frequency	Detected Concentration (mg/kg dw)		Reporting Limit (mg/kg dw)
		Minimum	Maximum	Min – Max
Antimony[a]	0/13	nd	nd	0.3 – 0.4
Arsenic	13/13	5.2	21.6	na
Cadmium	13/13	0.4	2.0	na
Chromium	13/13	23.1	101	na
Cobalt	13/13	5.6	9.1	na
Copper	13/13	38.3	103	na
Lead	13/13	27	101	na
Mercury	13/13	0.18	0.48	na
Molybdenum	13/13	1.8	3.6	na
Nickel[a]	13/13	16	27	na
Selenium	0/13	nd	nd	0.7 – 0.9
Silver	9/13	0.5	1.4	0.4 – 0.5
Thallium	2/13	0.3	0.6	0.3 – 0.4
Vanadium	13/13	49.4	70.7	na
Zinc	13/13	69 J	283 J	na

dw – dry weight
J – estimated concentration
na – not applicable
nd – not detected

Results for all metals in every co-located sediment sample are presented in Table 4-4, and compared to sediment quality standards (SQS) or screening levels (SL) and cleanup screening levels (CSLs) or maximum levels (ML). The sediment standards were developed for assessment of discrete samples and the comparison to composite samples provided here is intended to provide context for the sediment concentrations. Concentrations in bold exceed the respective SQS or SL. Mercury was detected at concentrations exceeding the SQS but not the CSL in two samples. None of the non-detected samples had RLs that exceeded the SQS/SL or CSL/ML for metals.

Table 4-4. Concentrations of metals in composite sediment samples co-located with benthic invertebrate tissue samples compared to SQS/SL and CSL/ML

Analyte	Concentration (mg/kg dw)														
	Area 1	Area 2E	Area 2W	Area 3	Area 4	Area 5	Area 6	Area 7	Area 8	Area 9	area 10	Area 11	Area 12	SQS/SL	CSL/ML
Antimony[a]	0.3 UJ	0.3 UJ	0.3 UJ	0.4 UJ	0.4 UJ	0.3 UJ	0.3 UJ	0.3 UJ	0.3 UJ	0.3 UJ	0.3 UJ	0.3 UJ	0.3 UJ	150	200
Arsenic	14.6	10.5	12.7	9.5	9.0	6.2	6.9	9.5	6.4	6.1	5.8	5.2	21.6	57	93
Cadmium	0.5	0.8	0.9	1.1	1.2	0.6	1.0	2.0	0.8	1.0	0.6	0.4	0.9	5.1	6.7
Chromium	28.9	34.3	31.5	43	38.9	26.8	32.1	38.1	30.8	34.1	101	23.1	28.1	260	270
Cobalt	7.0	7.4	6.9	9.1	8.2	6.6	7.3	7.3	6.6	6.7	6.4	5.6	6.0	na	na
Copper	70.2	74.1	64.1	103	82.9	65.8	61.1	94.2	49.7	52.6	42.6	38.3	96.2	390	390
Lead	41	54	60	66	60	31	40	71	39	43	50	27	101	450	530
Mercury	0.18	0.25	0.20	0.41	**0.48**	0.23	0.40	0.37	0.31	0.32	0.20	0.18	**0.47**	0.41	0.59
Molybdenum	2.1	3.4	3.0	3	3.5	2.1	2.6	3.6	2.5	2.5	2.3	1.8	2.6	na	na
Nickel[a]	19	21	17	27	25	21	23	23	22	21	19	16	18	140	370
Selenium	0.8 U	0.8 U	0.8 U	0.9 U	0.9 U	0.7 U	0.8 U	0.9 U	0.7 U	0.7 U	0.8 U	0.7 U	0.8 U	na	na
Silver	0.5 U	0.5	0.8	0.9	0.9	0.5 U	0.5	0.8	0.7	0.5	0.5 U	0.4 U	1.4	6.1	6.1
Thallium	0.3 U	0.3 U	0.3 U	0.4 U	0.4 U	0.6	0.3	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	0.3 U	na	na
Vanadium	55.3	59.9	53.7	70.7	67.6	56.2	61.1	59.5	52.0	55.5	52.1	49.4	53.4	na	na
Zinc	139 J	153 J	139 J	168 J	161 J	93 J	118 J	283 J	96 J	110 J	236 J	69 J	124 J	410	960

[a] Detected concentrations and RLs for these metals are compared to DMMP SL and ML guidelines.

CSL – cleanup screening level
DMMP – Dredged Material Management Program
dw – dry weight
J – estimated concentration
ML – maximum level
SL – screening level
na – not available (neither SQS/SL nor CSL/ML is available)
RL – reporting limit
SQS – sediment quality standards
U – not detected at reporting limit show

Bold indicates a concentration above the SQS or SL.

4.1.2 Butyltins

The results from the analyses of butyltins in benthic invertebrate tissue and co-located sediment samples are presented in Sections 4.1.2.1 and 4.1.2.2. Additional butyltin data from a subsequent sampling event are provided in Appendix B

4.1.2.1 Benthic invertebrate tissue

Table 4-5 presents a summary of the butyltins analyzed in benthic invertebrate composite tissue samples, including the number of detections, the range of detected butyltin concentrations, and the range of RLs. Butyltins were analyzed in tissue samples from 4 of the 13 areas (Areas 2W, 5, 6, and 9). Results for all butyltins in every benthic invertebrate tissue sample are presented in Table 4-6. TBT was detected in all benthic invertebrate tissue samples. The highest concentration of TBT in tissue samples was 390 µg/kg ww at Area 5. Dibutyltin was detected only in the tissue sample collected from Area 5. Monobutyltin was not detected in any tissue samples.

Table 4-5. Summary of butyltin concentrations in benthic invertebrate composite tissue samples

Analyte	Detection Frequency	Detected Concentration (µg/kg ww)		Reporting Limit (µg/kg ww)
		Minimum	Maximum	Min – Max
Monobutyltin as ion	0/4	nd	nd	7.3 – 11
Dibutyltin as ion	1/4	31 J	31 J	10 – 16
Tributyltin as ion	4/4	20	390	na

J – estimated concentration
na – not applicable
nd – not detected
ww – wet weight

Table 4-6. Concentrations of butyltins in benthic invertebrate composite tissue samples by area

Analyte	Concentration (µg/kg ww)			
	Area 2W	Area 5	Area 6	Area 9
Monobutyltin as ion	7.3 U	9.6 UJ	7.7 UJ	11 UJ
Dibutyltin as ion	10 U	31 J	11 UJ	16 UJ
Tributyltin as ion	20	390	91	88

J – estimated concentration
U – not detected at reporting limit shown
UJ – not detected at estimated reporting limit shown
ww – wet weight

4.1.2.2 *Sediment samples co-located with benthic invertebrate tissue samples*

Table 4-7 presents a summary of the butyltins analyzed in composite sediment samples co-located with benthic invertebrate tissue samples, including the number of detections, the range of detected concentrations, and the range of RLs. Results for all butyltins in every co-located composite sediment sample are presented in Table 4-8. TBT and dibutyltin were detected in all co-located sediment samples. The highest TBT and dibutyltin concentrations were 210 and 29 µg/kg dw, respectively, in samples collected from Area 3.

Table 4-7. Summary of butyltin concentrations in composite sediment samples co-located with benthic invertebrate tissue samples

Analyte	Detection Frequency	Detected Concentration (µg/kg dw)		Reporting Limit (µg/kg dw)
		Minimum	Maximum	Min – Max
Monobutyltin as ion	7/13	4.0	6.5 J	3.4 – 4.0
Dibutyltin as ion	13/13	6.1	29	na
Tributyltin as ion	13/13	26	210	na

dw – dry weight
J – estimated concentration
na – not applicable

Table 4-8. Concentrations of butyltins in composite sediment samples co-located with benthic invertebrate tissue samples

Analyte	Concentration (µg/kg dw)												
	Area 1	Area 2E	Area 2W	Area 3	Area 4	Area 5	Area 6	Area 7	Area 8	Area 9	Area 10	Area 11	Area 12
Monobutyltin as ion	4.7	6.5 J	4.0	6.4	4.7 J	3.6 U	4.9	5.0	3.6 U	3.4 U	3.6 U	4.0 U	3.7 U
Dibutyltin as ion	10	12	7.8	29	8.6	8.8	12	13	7.3	6.8	6.1	8.1	7.9
Tributyltin as ion	37	47	35	210	48	90	74	47	76 J	26	32	41	29

dw – dry weight

J – estimated concentration

U – not detected at reporting limit shown

4.1.3 PAHs

The results from the PAH analyses of benthic invertebrate tissue and co-located sediment samples are presented in Sections 4.1.3.1 and 4.1.3.2, respectively.

4.1.3.1 Benthic invertebrate tissue

Table 4-9 presents a summary of the PAHs analyzed in benthic invertebrate composite tissue samples, including the number of detections, the range of detected concentrations, and the range of RLs. Results for all PAHs analyzed in benthic invertebrate tissue samples are presented in Table 4-10. At least one PAH compound was detected in every tissue sample. All PAHs were detected in at least 2 tissue samples, and 17 of the 24 PAHs were detected in every tissue sample. The highest concentrations of total PAHs (3,760 µg/kg ww), total high-molecular-weight PAHs (HPAHs) (3,210 µg/kg ww), and total low-molecular weight PAHs (LPAHs) (550 µg/kg ww) were detected in the tissue sample collected from Area 3.

Table 4-9. Summary of PAH concentrations in benthic invertebrate composite tissue samples

Analyte	Detection Frequency	Detected Concentration (µg/kg ww)		Reporting Limit (µg/kg ww)
		Minimum	Maximum	Min – Max
1-Methylnaphthalene	2/13	6.9	16	4.6 – 5.0
2-Methylnaphthalene	3/13	7.8	21	4.6 – 5.0
Acenaphthene	7/13	4.7	37	4.6 – 5.0
Acenaphthylene	5/13	4.8	11	4.6 – 5.0
Anthracene	13/13	7.3	350	na
Benzo(a)anthracene	13/13	21	350	na
Benzo(a)pyrene	13/13	32	290	na
Benzo(b)fluoranthene	13/13	38	290	na
Benzo(g,h,i)perylene	13/13	14	110	na
Benzo(k)fluoranthene	13/13	38	290	na
Total benzofluoranthenes[a]	13/13	76	580	na
Chrysene	13/13	34	510	na
Dibenzo(a,h)anthracene	13/13	5.8	50	na
Dibenzofuran	4/13	6.7	27	4.6 – 5.0
Fluoranthene	13/13	34	760	na
Fluorene	8/13	4.6	46	4.8 – 5.0
Indeno(1,2,3-cd)pyrene	13/13	11	100	na
Naphthalene	5/13	4.8	34	4.6 – 5.0
Phenanthrene	13/13	9.1	220	na

Analyte	Detection Frequency	Detected Concentration (µg/kg ww)		Reporting Limit (µg/kg ww)
		Minimum	Maximum	Min – Max
Pyrene	13/13	80	900	na
Total HPAHs[a]	13/13	387	3,210	na
Total LPAHs[a]	13/13	18	550	na
Total PAHs[a]	13/13	419	3,760	na

[a] Totals were calculated following the data management rules described in Appendix A.

HPAH – high-molecular-weight polycyclic aromatic hydrocarbon. Total HPAHs are the sum of detected concentrations for fluoranthene, pyrene, benzo(a)anthracene, chrysene, total benzofluoranthenes, benzo(a)pyrene, indeno(1,2,3,-c,d)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene.

J – estimated concentration

LPAH – low-molecular-weight polycyclic aromatic hydrocarbon. Total LPAHs are the sum of detected concentrations for naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene

na – not applicable

PAH – polycyclic aromatic hydrocarbon

ww – wet weight

Table 4-10. Concentrations of PAHs in benthic invertebrate composite tissue samples

Analyte	Concentration (µg/kg ww)												
	Area 1	Area 2E	Area 2W	Area 3	Area 4	Area 5	Area 6	Area 7	Area 8	Area 9	area 10	Area 11	Area 12
1-Methylnaphthalene	4.7 U	4.8 U	4.8 U	4.8 U	4.6 U	4.7 U	4.8 U	16	4.8 U	4.8 U	4.8 U	5.0 U	6.9
2-Methylnaphthalene	4.7 U	4.8 U	4.8 U	11	4.6 U	4.7 U	4.8 U	21	4.8 U	4.8 U	4.8 U	5.0 U	7.8
Acenaphthene	5.7	7.7	12	11	4.6 U	4.7	4.8 U	36	4.8 U	4.8 U	4.8 U	5.0 U	37
Acenaphthylene	4.7 U	4.8	4.8 U	11	4.6 U	6.5	4.8 U	5.3	4.8 U	4.8 U	4.8 U	5.0 U	11
Anthracene	100	69	33	350	28	64	20	120	7.3	9.1	8.6	18	81
Benzo(a)anthracene	100	130	64	350	80	140	31	190	21	21	26	96	160
Benzo(a)pyrene	84	160	86	290	82	94	38	200	32	44	39	130	270
Benzo(b)fluoranthene	81	170	72	290	100	150	42	210	38	50	40	130	240
Benzo(g,h,i)perylene	32	62	42	100	33	34	17	71	14	18	21	48	110
Benzo(k)fluoranthene	81	170	72	290	100	95	42	210	38	50	40	130	240
Total benzofluoranthenes [a]	162	340	144	580	200	250	84	420	76	100	80	260	480
Chrysene	180	230	100	510	210	260	62	290	34	39	41	170	220
Dibenzo(a,h)anthracene	17	29	17	50	12	17	7.2	35	5.8	7.2	11	28	49
Dibenzofuran	4.7 U	4.8 U	6.7	15	4.6 U	4.7 U	4.8 U	27	4.8 U	4.8 U	4.8 U	5.0 U	14
Fluoranthene	220	280	190	760	84	540	53	600	46	34	55	88	360
Fluorene	9.0	9.1	14	46	4.6	12	4.8 U	39	4.8 U	4.8 U	4.8 U	5.0 U	33
Indeno(1,2,3-cd)pyrene	29	53	34	100	27	33	15	69	11	16	16	41	99
Naphthalene	4.7 U	4.8 U	4.8	6.7	4.6 U	4.7 U	4.8 U	34	4.8 U	4.8 U	14	5.0 U	20
Phenanthrene	42	46	63	130	22	100	12	150	11	9.1	19	24	220
Pyrene	160	290	190	470	130	380	80	700	240	140	99	260	900
Total HPAHs[a]	980	1,570	870	3,210	860	1,740	387	2,580	480	420	388	1,120	2,650
Total LPAHs[a]	160	137	127	550	55	190	32	380	18	18.2	42	42	400
Total PAHs[a]	1,140	1,710	990	3,760	910	1,930	419	2,960	500	440	430	1,160	3,050

[a] Totals were calculated following the data management rules described in Appendix A.
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
PAH – polycyclic aromatic hydrocarbon
U – not detected at reporting limit shown
ww – wet weight

4.1.3.2 Sediment

Table 4-11 presents a summary of the PAHs analyzed in composite sediment samples co-located with benthic invertebrate tissue samples, including the number of detections, the range of detected concentrations (in µg/kg dw), and the range of RLs. Results for all PAHs in every co-located sediment sample are presented in Table 4-12 in dry weight units. At least one PAH compound was detected in every co-located sediment sample. All PAHs were detected in at least 11 sediment samples, and 20 out of 24 PAHs were detected in every sediment sample. The highest concentrations of total PAHs (22,600 µg/kg dw), total HPAHs (17,100 µg/kg dw), and total LPAHs (5,500 µg/kg dw) were detected in the sample collected from Area 3.

Table 4-11. Summary of PAH concentrations in composite sediment samples co-located with benthic invertebrate tissue samples

Analyte	Detection Frequency	Detected Concentration (µg/kg dw)		Reporting Limit (µg/kg dw)
		Minimum	Maximum	Min – Max
1-Methylnaphthalene	11/13	4.7	18	4.6 – 19
2-Methylnaphthalene	12/13	7.0	23	19
Acenaphthene	13/13	8.5	190	na
Acenaphthylene	13/13	4.6	21	na
Anthracene	13/13	24	530	na
Benzo(a)anthracene	13/13	75	880	na
Benzo(a)pyrene	13/13	100	880	na
Benzo(b)fluoranthene	13/13	140	720	na
Benzo(g,h,i)perylene	13/13	59	440	na
Benzo(k)fluoranthene	13/13	82	840	na
Total benzofluoranthenes[a]	13/13	220	1,560	na
Chrysene	13/13	110	1,500	na
Dibenzo(a,h)anthracene	13/13	25	210	na
Dibenzofuran	12/13	7.3	85	19
Fluoranthene	13/13	150	8,000	na
Fluorene	13/13	10	230	na
Indeno(1,2,3-cd)pyrene	13/13	54	420	na
Naphthalene	12/13	9.7	110	19
Phenanthrene	13/13	70	4,600	na
Pyrene	13/13	230	4,500	na
Total HPAHs[a]	13/13	1,050	17,100	na
Total LPAHs[a]	13/13	131	5,500	na
Total PAHs[a]	13/13	1,190	22,600	na

[a] Totals were calculated following the data management rules described in Appendix A.
dw – dry weight
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
na – not applicable
PAH – polycyclic aromatic hydrocarbon

Table 4-12. Concentrations of PAHs in composite sediment samples

Analyte	Concentration (µg/kg dw)												
	Area 1	Area 2E	Area 2W	Area 3	Area 4	Area 5	Area 6	Area 7	Area 8	Area 9	area 10	Area 11	Area 12
1-Methylnaphthalene	19 U	5.0	7.6	8.5	8.5	5.2	5.1	18	4.6 U	5.7	4.7	8.4	17
2-Methylnaphthalene	19 U	8.7	12	18	14	9.0	7.9	15	7.8	8.0	7.0	12	23
Acenaphthene	19	18	17	67	20	8.5	11	40	8.7	10	13	23	190
Acenaphthylene	19	9.6	8.0	16	11	5.7	4.6	15	5.5	5.7	7.9	10	21
Anthracene	130	93	72	530	88	32	45	120	24	34	40	64	320
Benzo(a)anthracene	430	220	180	880	220	76	99	390	75	88	110	140	750
Benzo(a)pyrene	310	260	230	430	280	100	110	490	110	130	160	190	880
Benzo(b)fluoranthene	470	280	290	660	320	140	140	500	140	160	210	170	720
Benzo(g,h,i)perylene	170	130	140	180	150	62	60	230	59	71	94	110	440
Benzo(k)fluoranthene	340	270	230	660	260	82	120	410	88	130	130	170	840
Total benzofluoranthenes [a]	810	550	520	1,320	580	220	260	910	230	290	340	340	1,560
Chrysene	910	400	330	1,500	380	130	170	620	110	150	160	220	890
Dibenzo(a,h)anthracene	74	58	57	93	65	25	28	100	28	32	40	46	210
Dibenzofuran	19 U	14	16	85	16	7.6	7.4	44	7.3	7.6	9.4	16	69
Fluoranthene	1,100	350	360	8,000	310	150	170	590	170	150	220	290	1,600
Fluorene	38	30	27	230	30	14	15	45	10	13	15	25	130
Indeno(1,2,3-cd)pyrene	160	120	130	190	140	54	56	230	59	66	86	96	420
Naphthalene	19 U	10	14	14	16	12	9.7	41	13	12	14	27	110
Phenanthrene	200	140	180	4,600	180	73	76	230	70	72	97	150	840
Pyrene	860	390	470	4,500	420	230	240	830	360	290	310	300	1,900
Total HPAHs[a]	4,800	2,480	2,420	17,100	2,550	1,050	1,190	4,390	1,200	1,270	1,520	1,730	8,700
Total LPAHs[a]	410	300	320	5,500	350	145	161	490	131	147	187	300	1,610
Total PAHs[a]	5,200	2,780	2,740	22,600	2,890	1,190	1,350	4,880	1,330	1,410	1,710	2,030	10,300

[a] Totals were calculated following the data management rules described in Appendix A.

dw – dry weight
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
PAH – polycyclic aromatic hydrocarbons
U – not detected at reporting limit shown

Table 4-13 presents the results for PAHs in organic carbon (OC)-normalized units for every composite co-located sediment sample, and SQS and CSL criteria, which are in units of mg/kg OC. Concentrations in bold exceeded the respective SQS. Dibenzo(a,h)anthracene exceeded its respective SQS at Area 12, and fluoranthene and phenanthrene exceeded their respective SQS at Area 3. None of the RLs for non-detected PAHs exceeded the SQS.

Table 4-13. Concentrations of organic-carbon normalized PAHs in composite sediment samples

Analyte	Concentration (mg/kg OC)														
	Area 1	Area 2E	Area 2W	Area 3	Area 4	Area 5	Area 6	Area 7	Area 8	Area 9	Aea 10	Area 11	Area 12	SQS	CSL
2-Methylnaphthalene	0.92 U	0.70	0.41	0.93	0.60	0.50	0.45	0.61	0.54	0.65	0.66	1.5	1.4	38	64
Acenaphthene	0.92	1.5	0.58	3.5	0.86	0.47	0.63	1.6	0.60	0.81	1.2	2.8	11	16	57
Acenaphthylene	0.92	0.77	0.27	0.82	0.47	0.31	0.26	0.61	0.38	0.46	0.75	1.2	1.3	66	66
Anthracene	6.3	7.5	2.4	27	3.8	1.8	2.6	4.9	1.7	2.7	3.8	7.8	19	220	1,200
Benzo(a)anthracene	21	18	6.1	45	9.5	4.2	5.7	16	5.2	7.1	10	17	45	110	270
Benzo(a)pyrene	15	21	7.8	22	12	5.5	6.3	20	7.6	10	15	23	53	99	210
Benzo(g,h,i)perylene	8.3	10	4.8	9.3	6.5	3.4	3.4	9.3	4.1	5.7	8.9	13	27	31	78
Total benzofluoranthenes[a]	39	44	18	68.0	25	12	15	37	16	23	32	41	94.0	230	450
Chrysene	44	32	11	77	16	7.2	9.8	25	7.6	12	15	27	54	110	460
Dibenzo(a,h)anthracene	3.6	4.7	1.9	4.8	2.8	1.4	1.6	4.0	1.9	2.6	3.8	5.6	**13**	12	33
Dibenzofuran	0.92 U	1.1	0.54	4.4	0.69	0.42	0.43	1.8	0.51	0.61	0.89	1.9	4.2	15	58
Fluoranthene	53	28	12	**410**	13	8.3	9.8	24	12	12	21	35	96	160	1,200
Fluorene	1.8	2.4	0.92	12	1.3	0.77	0.86	1.8	0.69	1.0	1.4	3.0	7.8	23	79
Indeno(1,2,3-cd)pyrene	7.8	9.7	4.4	9.8	6.0	3.0	3.2	9.3	4.1	5.3	8.1	12	25	34	88
Naphthalene	0.92 U	0.81	0.48	0.72	0.69	0.66	0.56	1.7	0.90	0.97	1.3	3.3	6.6	99	170
Phenanthrene	9.7	11	6.1	**240**	7.8	4.0	4.4	9.3	4.9	5.8	9.2	18	51	100	480
Pyrene	42	31	16	230	18	13	14	34	25	23	29	36	110	1,000	1,400
Total HPAHs[a]	230	200	82.3	881	110	58.0	68.4	178	83.3	102	143	210	520	960	5,300
Total LPAHs[a]	20	24	11	280	15	8.01	9.25	20	9.10	11.9	17.6	36	97.0	370	780

[a] Totals were calculated following the data management rules described in Appendix A.
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
OC – organic carbon (normalized)
U – not detected at reporting limit shown
Bold indicates a concentration or reporting limit above the SQS.

4.1.4 PCBs

The results from the PCBs as Aroclors are presented in Sections 4.1.4.1 and 4.1.4.2, respectively.

4.1.4.1 Benthic invertebrate tissue

Table 4-14 presents a summary of PCB concentrations in benthic invertebrate composite tissue samples, including the number of detections, the range of detected concentrations, and the range of RLs. Results for PCBs in every benthic invertebrate tissue sample are presented in Table 4-15. Total PCBs were detected in all benthic invertebrate tissue samples and ranged from 93 µg/kg ww at Area 2W to 380 µg/kg ww at Area 2E. Aroclor 1016, 1221, 1232, 1242, and 1248 were not detected in any tissue samples.

Table 4-14. Summary of PCBs as Aroclors concentrations in benthic invertebrate composite tissue samples

Analyte	Detection Frequency	Detected Concentration (µg/kg ww)			Reporting Limit (µg/kg ww)
		Minimum	Maximum	Mean	Min – Max
Aroclor-1016	0/13	Nd	nd	nd	10 – 100
Aroclor-1221	0/13	Nd	nd	nd	10 – 450
Aroclor-1232	0/13	Nd	nd	nd	25 – 150
Aroclor-1242	0/13	Nd	nd	nd	10 – 250
Aroclor-1248	0/13	Nd	nd	nd	10 – 100
Aroclor-1254	12/13	53	180	100	100
Aroclor-1260	12/13	40	200	120	150
Total PCBs[a]	13/13	93	380	210	na

[a] Totals were calculated following the data management rules described in Appendix A.

na – not applicable

nd – not detected

PCB – polychlorinated biphenyl

ww – wet weight

Table 4-15. Concentrations of PCBs as Aroclors in benthic invertebrate composite tissue samples

Analyte	Concentration (µg/kg ww)												
	Area 1	Area 2E	Area 2W	Area 3	Area 4	Area 5	Area 6	Area 7	Area 8	Area 9	area 10	Area 11	Area 12
Aroclor-1016	50 U	100 U	10 U	66 U	50 U	50 U	50 U	56 U	54 U	50 U	56 U	50 U	50 U
Aroclor-1221	50 U	100 U	10 U	66 U	450 U	50 U	50 U	56 U	54 U	50 U	56 U	120 U	50 U
Aroclor-1232	150 U	100 U	25 U	66 U	50 U	50 U	50 U	56 U	54 U	50 U	56 U	50 U	50 U
Aroclor-1242	50 U	100 U	10 U	66 U	50 U	50 U	50 U	56 U	54 U	250 U	56 U	50 U	50 U
Aroclor-1248	50 U	100 U	10 U	66 U	50 U	50 U	50 U	56 U	54 U	50 U	56 U	50 U	50 U
Aroclor-1254	110	180	53	110	100 U	130 J	110	120 J	68	110	120	73	56
Aroclor-1260	150 U	200	40	130	150 J	160	100	140	96	120	130	110	59
Total PCBs	110	380	93	240	150 J	290 J	210	260 J	164	230	250	180	115

J – estimated concentration
PCB – polychlorinated biphenyl
U – not detected at reporting limit shown
ww – wet weight

4.1.4.2 Sediment

Table 4-16 presents a summary of PCBs in composite sediment samples co-located with benthic invertebrate tissue, including the number of detections, the range of detected concentrations, and the range of RLs. Results for all PCBs in every co-located sediment sample are presented in Table 4-17 and compared to the SQS and CSL. Concentrations in bold are greater than the SQS. Aroclors 1248, 1254, and 1260 were the only PCB Aroclors detected in co-located sediment samples. Total PCB concentrations ranged from 200 to 560 mg/kg dw. OC-normalized PCB concentrations exceeded the SQS at all sampling areas except Areas 1 and 7.

Table 4-16. Summary of concentrations of PCBs as Aroclors in composite sediment

Analyte	Unit	Detection Frequency	Detected Concentration		Reporting Limit
			Minimum	Maximum	Min – Max
Aroclor 1016	µg/kg dw	0/13	nd	nd	20 – 97
Aroclor 1221	µg/kg dw	0/13	nd	nd	20 – 97
Aroclor 1232	µg/kg dw	0/13	nd	nd	20 – 97
Aroclor 1242	µg/kg dw	0/13	nd	nd	20 – 97
Aroclor 1248	µg/kg dw	4/13	36	110	20 – 97
Aroclor 1254	µg/kg dw	11/13	100	200	170 – 210
Aroclor 1260	µg/kg dw	13/13	90	560	na
Total PCBs	µg/kg dw	13/13	200	560	na
Total PCBs	mg/kg OC	13/13	9.7	58 J	na

[a] Totals were calculated following the data management rules described in Appendix A.

dw – dry weight

J – estimated concentration

na – not applicable

nd – not detected

OC – organic carbon normalized

PCB – polychlorinated biphenyl

Table 4-17. Concentrations of PCBs as Aroclors in composite sediment sample co-located with benthic invertebrate tissue samples as dry weight, and organic-carbon normalized compared to SQS and CSL

Analyte	Unit	Area 1	Area 2E	Area 2W	Area 3	Area 4	Area 5	Area 6	Area 7	Area 8	Area 9	area 10	Area 11	Area 12	SQS	CSL
Aroclor-1016	µg/kg dw	20 U	60 U	35 U	20 U	59 U	20 U	58 U	20 U	58 U	97 U	97 U	60 U	59 U	na	na
Aroclor-1221	µg/kg dw	20 U	60 U	35 U	20 U	59 U	20 U	58 U	20 U	58 U	97 U	97 U	60 U	59 U	na	na
Aroclor-1232	µg/kg dw	20 U	60 U	35 U	20 U	59 U	20 U	58 U	20 U	58 U	97 U	97 U	60 U	59 U	na	na
Aroclor-1242	µg/kg dw	20 U	60 U	35 U	20 U	59 U	20 U	58 U	20 U	58 U	97 U	97 U	60 U	59 U	na	na
Aroclor-1248	µg/kg dw	20 U	89	110	20 U	59 U	55 J	58 U	36	58 U	97 U	97 U	60 U	59 U	na	na
Aroclor-1254	µg/kg dw	110	170	200	110	140	120	170	100	120	210 U	170 U	140	120	na	na
Aroclor-1260	µg/kg dw	90	280	240	150	200	180	330	160	230	560	460	340 J	200	na	na
Total PCBs[a]	µg/kg dw	200	540	550	260	340	360 J	500	300	350	560	460	480 J	320	na	na
Total PCBs[a]	mg/kg OC	9.7	**44**	**19**	**13**	**15**	**20 J**	**29**	12	**24**	**45**	**43**	**58 J**	**19**	12	65

[a] Totals were calculated following the rules described in Appendix A.

CSL – cleanup screening level
dw – dry weight
J – estimated concentration
na – not available (neither SQS/SL nor CSL/ML is available)
OC – organic carbon normalized
PCB – polychlorinated biphenyl
SQS – sediment quality values
U – not detected at reporting limit shown

Bold indicates a concentration or reporting limit above the SQS.

4.1.5 Lipids in benthic invertebrate tissue samples

Table 4-18 presents percent lipids measured in the benthic invertebrate tissue samples. Lipids ranged from 0.26 to 0.89% ww.

Table 4-18. Percent lipids in benthic invertebrate composite tissue samples

Analyte	Concentration (% ww)												
	Area 1	Area 2E	Area 2W	Area 3	Area 4	Area 5	Area 6	Area 7	Area 8	Area 9	area 10	Area 11	Area 12
Lipids	0.799	0.891	0.260	0.708	0.506	0.526	0.620	0.843	0.591	0.520	0.655	0.513	0.581

ww – wet weight

4.1.6 Grain size, TOC, and total solids in co-located sediment samples

Table 4-19 presents the results of grain size, TOC, and total solids analyses of co-located composite sediment samples. Percent fines ranged from 33.4% dw at Area 2W to 71.3% dw at Area 3. TOC ranged from 0.823% dw at Area 11 to 2.94% dw at Area 2W. Total solids ranged from 45.6% ww at Area 3 to 66.5% ww at Area 5.

Table 4-19. Grain size, TOC, and total solids in composite sediment samples co-located with benthic invertebrate tissue samples

Analyte	Unit	Area 1	Area 2E	Area 2W	Area 3	Area 4	Area 5	Area 6	Area 7	Area 8	Area 9	Area 10	Area 11	Area 12
Gravel (total)	% dw	18.6	4.0	7.8	0.8	0.8	8.9	3.9	17.5	1.6	0.5	0.4	1.1	0.7
Sand (total)	% dw	47.6	48.8	58.9	27.9	28.6	49.2	48.5	31.0	55.7	59.3	62.0	64.3	49.9
Silt (total)	% dw	20.5	30.4	19.8	49.4	48.2	28.2	33.0	33.8	26.7	27.2	25.6	24.6	34.5
Clay (total)	% dw	13.5	16.9	13.6	21.9	22.5	13.9	14.7	17.7	15.9	12.8	11.9	10.1	15.0
Fines (total) (percent silt+clay)	% dw	34.0	47.3	33.4	71.3	70.7	42.1	47.7	51.5	42.6	40.0	37.5	34.7	49.5
Fractional % phi >-1 (>2,000 microns)	% dw	18.6	4.0	7.8	0.8	0.8	8.9	3.9	17.5	1.6	0.5	0.4	1.1	0.7
Fractional % phi -1-0 (1,000-2,000 microns)	% dw	7.3	3.2	3.7	1.4	2.2	11.3	5.8	4.1	1.1	1.4	0.8	0.1 U	1.0
Fractional % phi 0-1 (500-1,000 microns)	% dw	6.5	5.8	10.4	2.0	1.8	10.7	5.5	3.7	2.2	3.2	1.0	0.9	0.9
Fractional % phi 1-2 (250-500 microns)	% dw	14.8	18.6	26.7	4.7	3.9	7.2	7.0	9.8	14.7	12.4	9.9	9.3	7.1
Fractional % phi 2-3 (125-250 microns)	% dw	12.5	13.4	14.3	7.4	7.9	10.3	14.9	6.3	23.8	23.8	28.5	31.2	20.7
Fractional % phi 3-4 (62.5-125 microns)	% dw	6.5	7.8	3.8	12.2	12.8	9.7	15.3	7.1	13.9	18.5	21.8	22.9	20.2
Fractional % phi 4-5 (31.2-62.5 microns)	% dw	3.0	5.8	3.6	12.0	11.6	8.1	10.7	7.9	8.0	10.0	10.7	8.7	11.1
Fractional % phi 5-6 (15.6-31.2 microns)	% dw	5.4	8.3	4.6	14.1	13.1	7.8	8.6	8.4	6.5	6.1	4.3	7.0	10.3
Fractional % phi 6-7 (7.8-15.6 microns)	% dw	6.2	8.7	6.3	12.7	12.9	6.9	7.8	9.7	6.3	5.4	6.4	5.1	7.6
Fractional % phi 7-8 (3.9-7.8 microns)	% dw	5.9	7.6	5.3	10.5	10.6	5.4	5.9	7.8	5.9	5.7	4.2	3.8	5.5
Fractional % phi 8-9 (1.95-3.9 microns)	% dw	4.5	5.5	4.5	7.5	7.6	4.4	4.6	6.2	4.9	3.7	3.3	2.9	4.5
Fractional % phi 9-10 (0.98-1.95 microns)	% dw	3.6	4.4	3.4	5.4	5.5	3.5	3.9	4.2	4.0	3.5	3.3	2.9	3.5
Fractional % phi 10+ (<0.98 micron)	% dw	5.4	7.0	5.7	9.0	9.4	6.0	6.2	7.3	7.0	5.6	5.3	4.3	7.0
TOC	% dw	2.06	1.24	2.94	1.94	2.32	1.81 J	1.74	2.47	1.44	1.24	1.06	0.823	1.66
Total solids	% ww	56.97	54.30	58.30	45.60	46.00	66.50 J	56.80	48.70	61.70	61.60	62.70	61.60	57.90

dw – dry weight
J – estimated concentration
TOC – total organic carbon
U – not detected at reporting limit shown
ww – wet weight

4.1.7 Comparison of non-detected results to analytical concentration goals

This section compares RLs and method detection limits (MDLs) for non-detected concentrations in benthic tissue and co-located sediment composite samples to site-specific analytical concentration goals (ACGs) that were presented in Appendix C (benthic invertebrate tissue) and Appendix D (sediment) of the QAPP (Windward 2009). The target detection limits for both the benthic tissue and co-located sediment analyses were also identified in these QAPP appendices and are presented in the tables in this section.

Actual MDLs and RLs may differ from the target detection limits as a result of necessary analytical dilutions or the adjustment of extracted sample volumes for some samples based on a preliminary screen of the sample prior to analysis. When sample extracts were diluted because the concentrations for one or more target analytes exceeded the upper end of the calibration curve, RLs from the original undiluted extract were reported for chemicals other than the target analytes that required dilution. The sample-specific RL is based on the lowest point of the calibration curve associated with each analysis, whereas the MDL is statistically derived following EPA methods (40 CFR 136). Both the RL and MDL will be elevated in cases where the sample extract required dilution. Detected concentrations between the MDL and RL were reported by the laboratories and flagged with a J-qualifier to indicate that the reported concentration was an estimate because it fell below the lowest point on the calibration curve. The analytical laboratory performed the appropriate sample cleanups to achieve the lowest possible detection limits.

The RLs and MDLs for benthic invertebrate tissue samples were lower than the risk-based ACGs developed for benthic invertebrate tissue for all analytes. The RLs for co-located sediment samples were lower than the applicable SQS or SL, except for one result as summarized in Table 4-20. The RL for dibenzofuran in one sample was above the SQS, and the associated MDL in this sample was below the SQS. The RL and MDL for this sample were elevated as a result of an analytical dilution.

Table 4-20. Comparison of co-located composite sediment RLs and MDLs to the benthic invertebrate ACGs for sediment

Analyte	Unit	No. of Detected Results	Range of Detected Results	No. of Non-Detected Results	Range of RLs for Non-Detected Results	No. of RLs > ACG	Range of MDLs for Non-Detected results	No. of MDLs > ACG	Target MDL	Benthic Invertebrate ACGa
Metals										
Antimony	mg/kg dw	0	nd	13	0.3 – 0.4	0	0.019 – 0.024	0	0.013	150
Silver	mg/kg dw	9	0.5 – 1.4	4	0.4 – 0.5	0	0.16 – 0.17	0	0.006	6.1
PAHs										
2-Methylnaphthalene	mg/kg OC	12	7 – 23	1	19	0	0.32	0	na[b]	38
Dibenzofuran	mg/kg OC	12	7.3 – 85	1	19	1	0.26	0	na[b]	15
Naphthalene	mg/kg OC	12	9.7 – 110	1	19	0	0.24	0	na[b]	99

[a] In Appendix D of the QAPP, the OC-normalized ACGs were converted to dry weight for comparison to dry weight RLs and MDLs using an OC content of 0.5%. In the comparison presented in this table, the RLs and MDLs were converted to OC-normalized values using sample-specific TOC contents for comparison to OC-normalized ACGs.

[b] The target MDLs presented in the QAPP are dry weight values.

ACG – analytical concentration goal
dw – dry weight
MDL – method detection limit
na – not applicable
OC – organic carbon
QAPP – quality assurance project plan
PAH – polycyclic aromatic hydrocarbon
RL – reporting limit
TOC – total organic carbon

4.2 DATA VALIDATION RESULTS

The benthic invertebrate tissue and co-located sediment composite samples were submitted to ARI and analyzed in two sample delivery groups (SDGs): SDG OG18 (tissue) and SDG NX45 (sediment). Independent full-level data validation was performed by EcoChem on all results. The data validation included a review of all QC summary forms, including initial calibration, continuing calibration verification (CCV), internal standard, surrogate, laboratory control sample, laboratory control sample duplicate, matrix spike (MS), matrix spike duplicate (MSD), standard reference material (SRM), and interference check sample summary forms. The majority of the data did not require qualification, or were qualified with a J, indicating an estimated value. No results were rejected as a result of data validation. Based on the information reviewed, the overall data quality was considered acceptable for all uses, as qualified. Issues that resulted in the qualification of data are summarized below. Detailed information regarding every qualified sample is presented in Appendix D. SRM samples were analyzed with the sediment samples and all results were considered acceptable.

- Results for various chemicals (13 results each for antimony and silver, 4 results for nickel, and 2 results for selenium in tissue samples; 13 results each for antimony and zinc, and 1 result each for Aroclor 1260, TBT, TOC, and total solids in co-located sediment) were qualified as estimated (J or UJ) because MS/MSD, CCV, or contract-required detection limit standard recoveries were outside of control limits. The MS recoveries for silver in tissue and antimony in sediment were very low, 7.8% and 2.1%, respectively. The post digestion spike recoveries for these metals were within QC limits (102.7% for silver and 97.3% for antimony); therefore, results were not rejected, but were qualified as estimated. The results of all other QC samples were within acceptance criteria for these metals. The results for silver in tissue and antimony may have a strong negative bias as a result of matrix interferences. Aroclor 1260 and TBT were not recovered from their respective MS/MSD (Aroclor 1260) or MSD (TBT) sediment samples, possibly because the native concentrations of both of these analytes were higher than the spiked concentrations. The MS result for TBT was within QC limits and was spiked at the same level as the MSD.
- Internal standard recoveries for p-terphenyl-d14 were below QC limits in samples EW08-BI05-T, EW08-BI06-T, and EW08-BI09-T, resulting in the J- or UJ-qualification of the monobutyltin and dibutyltin results in these samples.
- The relative percent differences between the results of dual-column analyses for Aroclor 1254 or Aroclor 1260 in three samples (EW08-BI04-T, EW08-BI05-T, and EW08-BI07-T) were outside of control limits. These results were J-qualified to indicate estimated concentrations.

- When more than one Aroclor is present in a sample, the potential exists for a high bias from the contribution of one Aroclor to another caused by common peaks or peaks that cannot be completely resolved. Analytical peaks are selected, and Aroclor identification is made based on the best resolution possible for that particular sample. Reported Aroclor concentrations were reported based on the individual Aroclors that provided the best match to the observed sample pattern. RLs for seven individual Aroclor results were Y-qualified by the laboratory as non-detects at elevated RLs because of overlapping Aroclor patterns. The Y-qualifier indicates that chromatographic interference in the sample prevented adequate resolution of the compound at the standard RLs. The data validators translated the laboratory Y-qualifier a U data validation qualifier.

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